CHAPTER 10 (Odd)

1. $\mathscr{E} = k\frac{Q_1}{r^2} = \frac{(9 \times 10^9)(4\ \mu C)}{(2\ m)^2} = \mathbf{9 \times 10^3\ N/C}$

3. $C = \frac{Q}{V} = \frac{1400\ \mu C}{20\ V} = \mathbf{70\ \mu F}$

5. $\mathscr{E} = \frac{V}{d} = \frac{100\ mV}{2\ mm} = \mathbf{50\ V/m}$

7. $V = \frac{Q}{C} = \frac{160\ \mu C}{4\ \mu F} = 40\ V$
   $\mathscr{E} = \frac{V}{d} = \frac{40\ V}{5\ mm} = \mathbf{8 \times 10^3\ V/m}$

9. $C = 8.85 \times 10^{-12}\,\epsilon_r\frac{A}{d} = 8.85 \times 10^{-12}(2.5)\frac{(75 \times 10^{-3} m^2)}{1.77\ mm} = \mathbf{937.5\ pF}$

11. $C = \epsilon_r C_o \Rightarrow \epsilon_r = \frac{C}{C_o} = \frac{0.006\ \mu F}{1200\ pF} = \mathbf{5\ (mica)}$

13. a. $\mathscr{E} = \frac{V}{d} = \frac{200\ V}{0.2\ mm} = \mathbf{10^6\ V/m}$

    b. $Q = \epsilon\mathscr{E}A = \epsilon_r\epsilon_o\mathscr{E}A = (7)(8.85 \times 10^{-12})(10^6\ V/m)(0.08\ m^2) = \mathbf{4.96\ \mu C}$

    c. $C = \frac{Q}{V} = \frac{4.96\ \mu C}{200\ V} = \mathbf{0.0248\ \mu F}$

15. $d = \frac{8.85 \times 10^{-12}\epsilon_r A}{C} = \frac{(8.85 \times 10^{-12})(5)(0.02\ m^2)}{0.006\ \mu F} = 0.1475\ mm = 147.5\ \mu m$

    $d = 0.1475\ \cancel{mm}\left[\frac{10^{-3}\ \cancel{m}}{1\ \cancel{mm}}\right]\left[\frac{39.37\ \cancel{in.}}{1\ \cancel{m}}\right]\left[\frac{1000\ mils}{1\ \cancel{in.}}\right] = 5.807\ mils$

    $5.807\ \cancel{mils}\left[\frac{5000\ V}{\cancel{mil}}\right] = \mathbf{29{,}035\ V}$

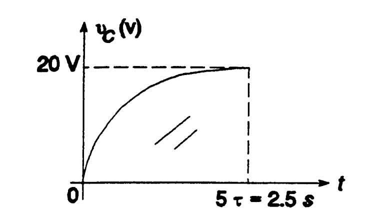
17. a. $\tau = RC = (10^5\ \Omega)(5\ \mu F) = \mathbf{0.5\ s}$

    b. $v_C = E(1 - e^{-t/\tau}) = \mathbf{20(1 - e^{-t/0.5})}$

    c. $1\tau = 0.632(20\ V) = \mathbf{12.64\ V}$, $3\tau = 0.95(20\ V) = \mathbf{19\ V}$
       $5\tau = 0.993(20\ V) = \mathbf{19.87\ V}$

    d. $i_C = \frac{20V}{100\ k\Omega}e^{-t/\tau} = \mathbf{0.2 \times 10^{-3}e^{-t/0.5}}$
       $v_R = Ee^{-t/\tau} = \mathbf{20e^{-t/0.5}}$

e.



iC (mA)
0.2
0
5 τ = 2.5 s
t

19. a. $\tau = RC = (2.2\ \text{k}\Omega + 3.3\ \text{k}\Omega)1\ \mu\text{F} = (5.5\ \text{k}\Omega)(1\ \mu\text{F}) = \mathbf{5.5\ ms}$

b. $v_C = E(1 - e^{-t/\tau}) = \mathbf{100(1 - e^{-t/5.5\times10^{-3}})}$

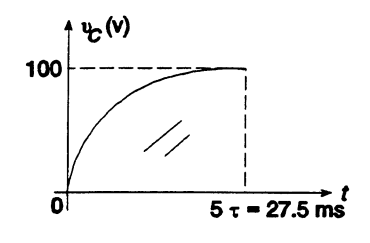
c. $1\tau = \mathbf{63.21\ V},\ 3\tau = \mathbf{95.02\ V},\ 5\tau = \mathbf{99.33\ V}$

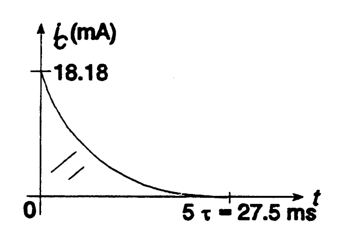
d. $i_C = \dfrac{E}{R_T}e^{-t/\tau} = \dfrac{100\ \text{V}}{5.5\ \text{k}\Omega}e^{-t/\tau} = \mathbf{18.18 \times 10^{-3} e^{-t/5.5\times10^{-3}}}$

$V_{R_2} = \dfrac{3.3\ \text{k}\Omega(100\ \text{V})}{3.3\ \text{k}\Omega + 2.2\ \text{k}\Omega} = 60\ \text{V}$

$v_R = v_{R_2} = \mathbf{60e^{-t/5.5\times10^{-3}}}$

e.





21. a. $\tau = RC = (2\ \text{k}\Omega + 3\ \text{k}\Omega)2\ \mu\text{F} = (5\ \text{k}\Omega)(2\ \mu\text{F}) = \mathbf{10\ ms}$

b. $v_C = \mathbf{50(1 - e^{-t/10\times10^{-3}})}$

c. $i_C = \dfrac{50\ \text{V}}{5\ \text{k}\Omega}e^{-t/\tau} = \mathbf{10 \times 10^{-3} e^{-t/10\times10^{-3}}}$

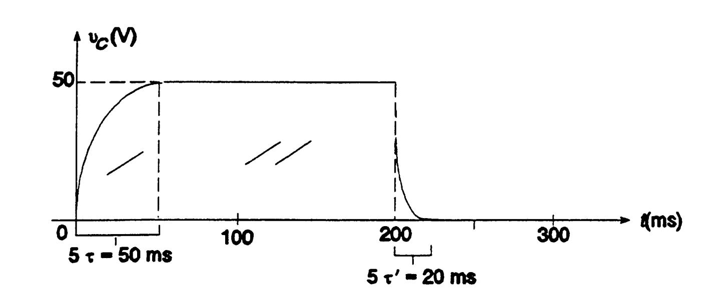
d. $t = 100$ ms: $v_C = 50(1 - e^{-t/\tau}) = 50(1 - e^{-10}) = 49.997\ \text{V} \cong \mathbf{50\ V}$
$i_C \cong 0$ mA

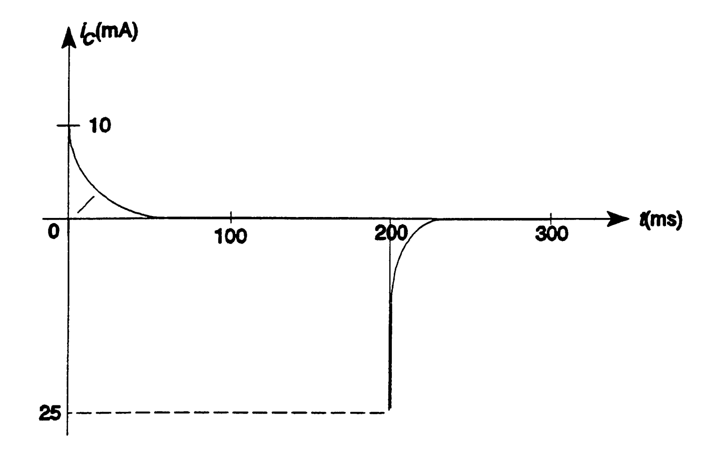
e. $\tau' = R_2C = (2\ \text{k}\Omega)(2\ \mu\text{F}) = 4$ ms

$v_C = 50e^{-t/\tau'} = \mathbf{50e^{-t/4\times10^{-3}}}$

$i_C = \dfrac{50\ \text{V}}{2\ \text{k}\Omega}e^{-t/\tau'} = \mathbf{25 \times 10^{-3} e^{-t/4\times10^{-3}}}$

f.





23. a. $\tau = R_1C = (10^5\ \Omega)(10\text{ pF}) = 1\ \mu\text{s}$

$v_C = \mathbf{80(1 - e^{-t/1\times10^{-6}})}$

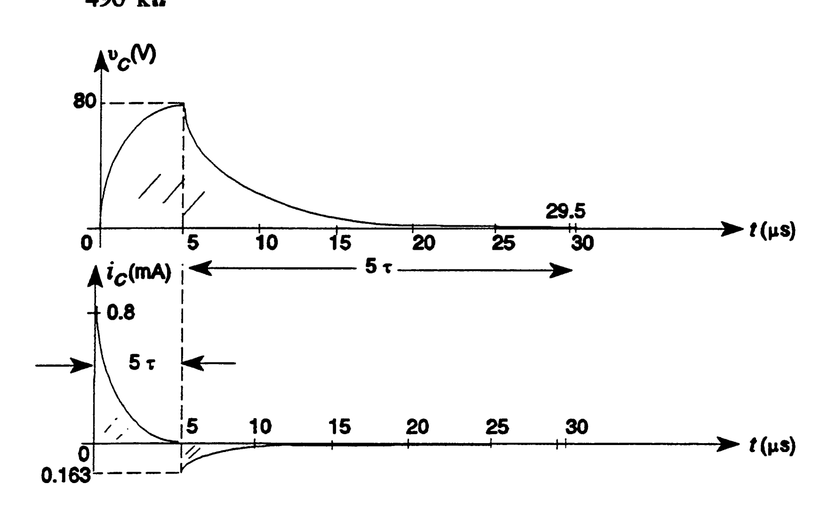
b. $i_C = \dfrac{80\text{ V}}{100\text{ k}\Omega}e^{-t/\tau} = \mathbf{0.8 \times 10^{-3}e^{-t/1\times10^{-6}}}$

c. $\tau' = R'C = (490\text{ k}\Omega)(10\text{ pF}) = 4.9\ \mu\text{s}$

$v_C = 80e^{-t/\tau'} = \mathbf{80e^{-t/4.9\times10^{-6}}}$

$i_C = \dfrac{80\text{ V}}{490\text{ k}\Omega}e^{-t/\tau'} = \mathbf{0.163 \times 10^{-3}e^{-t/4.9\times10^{-6}}}$

d.

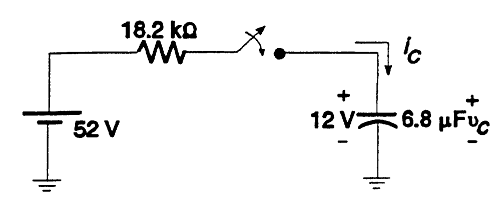


25. a. $\tau = RC = (2\ \text{m}\Omega)(1000\ \mu\text{F}) = 2\ \mu\text{s}$
$5\tau = \mathbf{10\ \mu s}$

b. $I_m = \dfrac{V}{R} = \dfrac{6\ \text{V}}{2\ \text{m}\Omega} = \mathbf{3\ kA}$

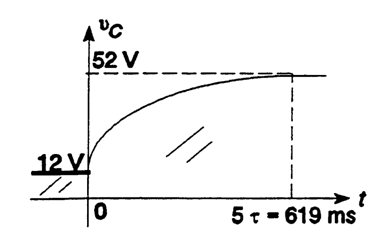
c. yes

27. a.



$\tau = RC = (18.2\ \text{k}\Omega)(6.8\ \mu\text{F}) = 123.8\ \text{ms}$
$v_C = V_f + (V_i - V_f)e^{-t/\tau}$
$= 52\ \text{V} + (12\ \text{V} - 52\ \text{V})e^{-t/123.8\ \text{ms}}$
$v_C = \mathbf{52\ V - 40\ V}e^{\mathbf{-t/123.8\ ms}}$
$v_R(0+) = 52\ \text{V} - 12\ \text{V} = 40\ \text{V}$
$i_C = \dfrac{40\ \text{V}}{18.2\ \text{k}\Omega}e^{-t/123.8\ \text{ms}}$
$= \mathbf{2.198\ mA}e^{\mathbf{-t/123.8\ ms}}$

b.



i_C — 2.198 mA — 0 — 5 τ = 619 ms — t

29. $i_C = \underbrace{\dfrac{1}{2}\dfrac{E}{R}}_{\frac{1}{2}I_m} = \underbrace{\dfrac{E}{R}}_{I_m}e^{-t/\tau}$

$\dfrac{1}{2} = e^{-t/\tau} \Rightarrow \log_e \dfrac{1}{2} = -t/\tau \Rightarrow t = -\tau \log_e \dfrac{1}{2}$

$t = -2 \times 10^{-6} \log_e \dfrac{1}{2}$
$= -(2 \times 10^{-6})(-0.693)$
$= \mathbf{1.386\ \mu s}$

31. Eq. 10.23:

$t = -\tau \log_e \left[1 - \dfrac{v_C}{E}\right]$

$10\ \text{s} = -\tau \log_e \underbrace{\left[1 - \dfrac{12\ \text{V}}{20\ \text{V}}\right]}_{.04}$

$\underbrace{\qquad}_{-0.9163}$

$\tau = \dfrac{10\ \text{s}}{0.9163} = 10.913\ \text{s}$

$\tau = RC \Rightarrow R = \dfrac{\tau}{C} = \dfrac{10.913\ \text{s}}{200\ \mu\text{F}} = \mathbf{54.567\ k\Omega}$

33. a. $\tau = RC = (1\ \text{M}\Omega)(0.2\ \mu\text{F}) = 0.2\ \text{s}$

$v_C = \mathbf{60(1 - e^{-t/0.2s})}$

$i_C = \frac{E}{R}e^{-t/\tau} = \frac{60\ \text{V}}{1\ \text{M}\Omega}e^{-t/0.2s} = \mathbf{60 \times 10^{-6}e^{-t/0.2s}}$

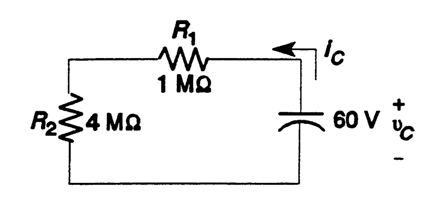
$v_{R_1} = Ee^{-t/\tau} = \mathbf{60e^{-t/0.2s}}$

v_C: 0.5 s = **55.07 V**
1 s = **59.576 V**

i_C: 0.5 s = **4.93 μA**
1 s = **0.404 μA**

v_{R_1}: 0.5 s = **4.93 V**
1 s = **0.404 V**

b.



$\tau' = RC = (1\ \text{M}\Omega + 4\ \text{M}\Omega)(0.2\ \mu\text{F})$
$= (5\ \text{M}\Omega)(0.2\ \mu\text{F})$
$= 1\ \text{s}$

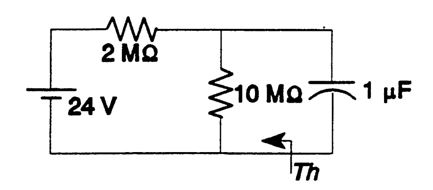
$i_C = \frac{60\ \text{V}}{5\ \text{M}\Omega}e^{-t} = 12 \times 10^{-6}e^{-t}$

$8 \times 10^{-6} = 12 \times 10^{-6}e^{-t}$
$0.667 = e^{-t}$
$\log_e 0.667 = -t$
$-0.405 = -t$
$t = \mathbf{0.405\ s}$

$v_C = 60e^{-t/\tau'}$
$10 = 60e^{-t}$
$0.1667 = e^{-t}$
$\log_e 0.1667 = -t$
$-1.792 = -t$
$t = 1.792\ \text{s}$

Longer = 1.792 s − 0.405 s = **1.387 s**

35. a.



$R_{Th} = 2\ \text{M}\Omega \parallel 10\ \text{M}\Omega = 1.667\ \text{M}\Omega$

$E_{Th} = \frac{10\ \text{M}\Omega(24\ \text{V})}{10\ \text{M}\Omega + 2\ \text{M}\Omega} = 20\ \text{V}$

$v_C = E_{Th}(1 - e^{-t/\tau})$
$= 20\ \text{V}(1 - e^{-4\tau/\tau})$
$= 20\ \text{V}(1 - e^{-4})$
$= 20\ \text{V}(1 - 0.0183)$
$= \mathbf{19.634\ V}$

$$\tau = R_{Th}C = (1.667\text{ M}\Omega)(1\ \mu\text{F}) = 1.667\text{ s}$$

$$i_C = \frac{E}{R}e^{-t/\tau}$$

$$3\ \mu\text{A} = \frac{20\text{ V}}{1.667\text{ M}\Omega}e^{-t/1.667\text{s}}$$

$$0.25 = e^{-t/1.667\text{s}}$$

$$\log_e 0.25 = -t/1.667\text{ s}$$

$$t = -(1.667\text{ s})(-1.386)$$

$$= \mathbf{2.31\text{ s}}$$

c.

$$v_{\text{meter}} = v_C$$

$$v_C = E_{Th}(1 - e^{-t/\tau})$$

$$10\text{ V} = 20\text{ V}(1 - e^{-t/1.667\text{s}})$$

$$0.5 = 1 - e^{-t/1.667\text{s}}$$

$$-0.5 = -e^{-t/1.667\text{s}}$$

$$\log_e 0.5 = -t/1.667\text{ s}$$

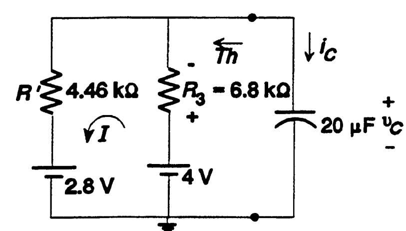
$$t = -(1.667\text{ s})(-0.693)$$

$$= \mathbf{1.155\text{ s}}$$

37. a. Source conversion:

$$E = IR_1 = (5\text{ mA})(0.56\text{ k}\Omega) = 2.8\text{ V}$$

$$R' = R_1 + R_2 = 0.56\text{ k}\Omega + 3.9\text{ k}\Omega = 4.46\text{ k}\Omega$$



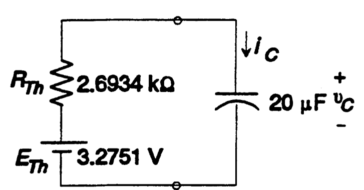
$$R_{Th} = 4.46\text{ k}\Omega \parallel 6.8\text{ k}\Omega = 2.6934\text{ k}\Omega$$

$$I = \frac{4\text{V} - 2.8\text{ V}}{6.8\text{ k}\Omega + 4.46\text{ k}\Omega} = \frac{1.2\text{ V}}{11.26\text{ k}\Omega} = 0.1066\text{ mA}$$

$$E_{Th} = 4\text{ V} - (0.1066\text{ mA})(6.8\text{ k}\Omega)$$

$$= 4\text{ V} - 0.7249\text{ V}$$

$$= 3.2751\text{ V}$$



$$v_C = 3.2751(1 - e^{-t/\tau})$$

$$\tau = RC = (2.6934\text{ k}\Omega)(20\ \mu\text{F})$$

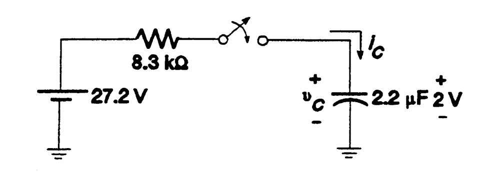
$$= 53.87\text{ ms}$$

$$v_C = \mathbf{3.2751(1 - e^{-t/53.87\text{ ms}})}$$

$$i_C = \frac{3.2751\text{ V}}{2.6934\text{ k}\Omega}e^{-t/\tau}$$

$$= \mathbf{1.216 \times 10^{-3}e^{-t/53.87\text{ ms}}}$$

39. a. Source conversion:



$\tau = RC = (8.3\text{ k}\Omega)(2.2\ \mu\text{F}) = 18.26\text{ ms}$

$v_C = V_f + (V_i - V_f)e^{-t/\tau}$

$= 27.2\text{ V} + (2\text{ V} - 27.2\text{ V})e^{-t/18.26\text{ ms}}$

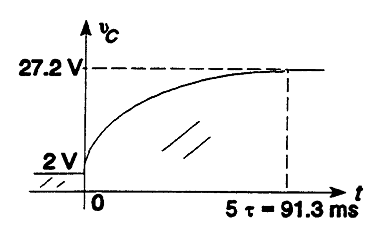
$v_C = \mathbf{27.2\ V - 25.2\ V}e^{-t/18.26\text{ ms}}$

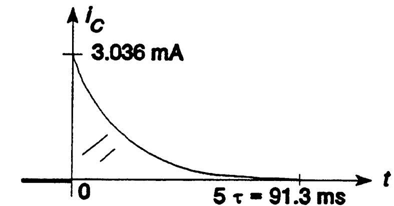
$v_R(0+) = 27.2\text{ V} - 2\text{ V} = 25.2\text{ V}$

$i_C = \dfrac{25.2\text{ V}}{8.3\text{ k}\Omega}e^{-t/18.26\text{ ms}}$

$i_C = \mathbf{3.036\ mA}e^{-t/18.26\text{ ms}}$

b.





41. $i_C = C\dfrac{\Delta V}{\Delta t}$: $i_C = 0.06 \times 10^{-6}\dfrac{\Delta V}{\Delta t}$

0 – 4 ms: $i_C = 0.06 \times 10^{-6}\left[\dfrac{20\text{ V}}{4\text{ ms}}\right] = 0.3\text{ mA}$

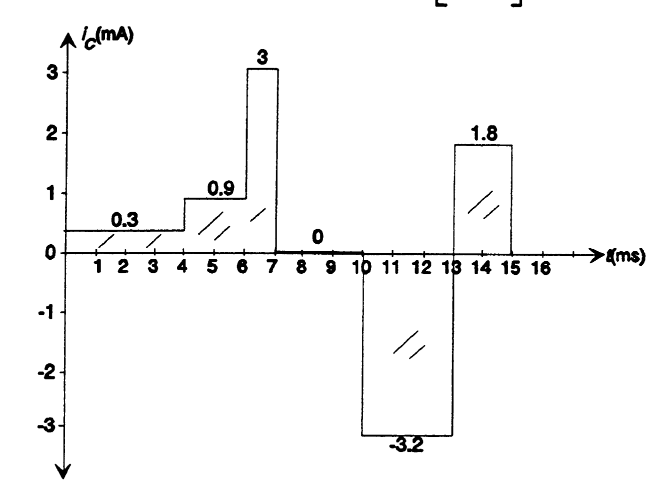
4 – 6 ms: $i_C = 0.06 \times 10^{-6}\left[\dfrac{30\text{ V}}{2\text{ ms}}\right] = 0.9\text{ mA}$

6 – 7 ms: $i_C = 0.06 \times 10^{-6}\left[\dfrac{50\text{ V}}{1\text{ ms}}\right] = 3\text{ mA}$

7 – 10 ms: $i_C = 0\text{ mA}$

10 – 13 ms: $i_C = -0.06 \times 10^{-6}\left[\dfrac{160\text{ V}}{3\text{ ms}}\right] = -3.2\text{ mA}$

13 – 15 ms: $i_C = 0.06 \times 10^{-6}\left[\dfrac{60\text{ V}}{2\text{ ms}}\right] = 1.8\text{ mA}$



43. $i_C = C\dfrac{\Delta V_C}{\Delta t} \Rightarrow \Delta V_C = \dfrac{\Delta t}{C}(i_C)$

0 − 4 ms: $i_C = 0$ mA, $\Delta V_C = 0$ V

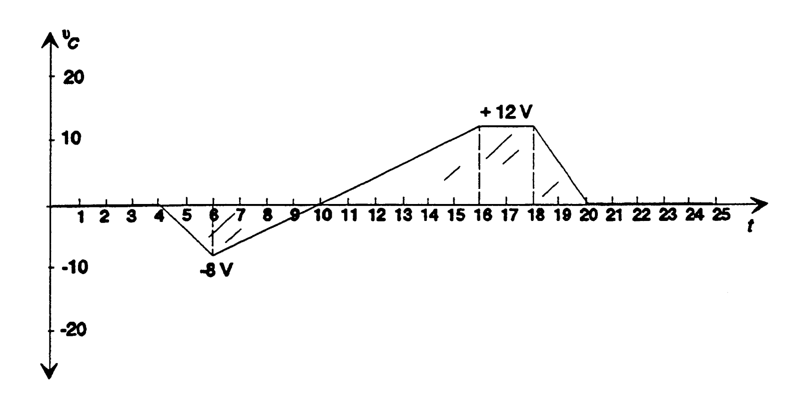
4 − 6 ms: $i_C = -80$ mA, $\Delta V_C = \dfrac{(2 \text{ ms})}{20\ \mu\text{F}}(-80 \text{ mA}) = -8$ V

6 − 16 ms: $i_C = +40$ mA, $\Delta V_C = \dfrac{(10 \text{ ms})}{20\ \mu\text{F}}(40 \text{ mA}) = +20$ V

16 − 18 ms: $i_C = 0$ mA, $\Delta V_C = 0$ V

18 − 20 ms: $i_C = -120$ mA, $\Delta V_C = \dfrac{(2 \text{ ms})}{20\ \mu\text{F}}(-120 \text{ mA}) = -12$ V

20 − 25 ms: $i_C = 0$ mA, $\Delta V_C = 0$ V



45. $V_1 = \mathbf{10\ V}$, $Q_1 = C_1V_1 = (6\ \mu\text{F})(10\ \text{V}) = \mathbf{60\ \mu C}$
$Q_2 = Q_3 = C_TV = (4\ \mu\text{F})(10\ \text{V}) = \mathbf{40\ \mu C}$
$V_2 = Q_2/C_2 = 40\ \mu\text{C}/6\ \mu\text{F} = \mathbf{6.67\ V}$
$V_3 = Q_3/C_3 = 40\ \mu\text{C}/12\ \mu\text{F} = \mathbf{3.33\ V}$

47. a. $C_T = \dfrac{(8\ \mu\text{F})(24\ \mu\text{F})}{8\ \mu\text{F} + 24\ \mu\text{F}} = 6\ \mu\text{F}$
$\tau = RC = (20\ \text{k}\Omega)(6\ \mu\text{F}) = 120$ ms
$v_{ab} = v_{C_T} = 100(1 - e^{-t/120\text{ms}})$
At $t = 100$ ms

$$v_{ab} = 100\left[1 - e^{-\frac{100\text{ms}}{120\text{ms}}}\right] = 100(1 - e^{-0.833})$$
$$= 100(.5654) = \mathbf{56.54\ V}$$

b, c.

a
Q_1 8 µF
c
Q_2 24 µF
b

$Q_1 = Q_2 = C_TV_{ab} = (6\ \mu\text{F})(56.54\ \text{V}) = 339.24\ \mu\text{C}$
$C_1V_1 = C_2V_2$
$8\ \mu\text{F}\ V_{ac} = 24\ \mu\text{F}\ V_{cb} = 339.24\ \mu\text{C}$
and $V_{ac} = \dfrac{339.24\ \mu\text{C}}{8\ \mu\text{F}} = \mathbf{42.405\ V}$
$V_{cb} = \dfrac{339.24\ \mu\text{C}}{24\ \mu\text{F}} = \mathbf{14.135\ V}$

d. $V_{da} = E - V_{ab} = 100\text{ V} - 56.54\text{ V} = \mathbf{43.46\text{ V}}$

e.

20 kΩ
+ v_{R_2} − R_2 40 kΩ
6 μF + 100 V −

$$i_C = \frac{E}{R_T}e^{-t/\tau},\ \tau = RC = (60\text{ k}\Omega)(6\ \mu\text{F}) = 360\text{ ms}$$

$$i_C = \frac{100\text{ V}}{60\text{ k}\Omega}e^{-t/360\text{ms}} = 1.667 \times 10^{-3}e^{-t/360\text{ms}}$$

$$v_{R_2} = i_C R_2 = (1.667\text{ mA})(40\text{ k}\Omega)e^{-t/360\text{ms}}$$
$$= 66.67e^{-t/360\text{ms}}$$

$$20 = 66.67e^{-t/360\text{ms}} \Rightarrow\ 0.3 = e^{-t/360\text{ms}}$$
$$\log_e 0.3 = -t/360\text{ ms}$$
$$-1.204 = -t/360\text{ ms}$$
$$t = 1.204(360\text{ ms})$$
$$= \mathbf{433.44\text{ ms}}$$

49. $W_C = \frac{1}{2}CV^2 = \frac{1}{2}(120\text{ pF})(12\text{ V})^2 = \mathbf{8{,}640\text{ pJ}}$

51. a. $W_C = \frac{1}{2}CV^2 = \frac{1}{2}(1000\ \mu\text{F})(100\text{ V})^2 = \mathbf{5\text{ J}}$

b. $Q = CV = (1000\ \mu\text{C})(100\text{ V}) = \mathbf{0.1\text{ C}}$

c. $I = Q/t = 0.1\text{ C}/(1/2000) = \mathbf{200\text{ A}}$

d. $P = V_{av}I_{av} = W/t = 5\text{ J}/(1/2000\text{ s}) = \mathbf{10{,}000\text{ W}}$

e. $t = Q/I = 0.1\text{ C}/10\text{ mA} = \mathbf{10\text{ s}}$

CHAPTER 10 (Even)

2. $\mathscr{E} = \dfrac{kQ}{r^2} \Rightarrow r = \sqrt{\dfrac{kQ}{\mathscr{E}}} = \sqrt{\dfrac{(9 \times 10^9)(0.064\ \mu\text{C})}{36\ \text{N/C}}} = \mathbf{4\ m}$

4. $Q = CV = (0.05\ \mu\text{F})(45\ \text{V}) = \mathbf{2.25\ \mu C}$

6. $d = 4\ \cancel{\text{mils}} \left[\dfrac{10^{-3}\ \cancel{\text{in.}}}{1\ \cancel{\text{mil}}}\right]\left[\dfrac{1\ \text{m}}{39.37\ \cancel{\text{in.}}}\right] = 0.102\ \text{mm}$

$\mathscr{E} = \dfrac{V}{d} = \dfrac{100\ \text{mV}}{0.102\ \text{mm}} = \mathbf{980.39\ V/m}$

8. $C = 8.85 \times 10{-}12\epsilon_r \dfrac{A}{d} = 8.85 \times 10^{-12}(1)\dfrac{(0.075\ \text{m}^2)}{1.77\ \text{mm}} = \mathbf{375\ pF}$

10. $C = 8.85 \times 10^{-12}\epsilon_r \dfrac{A}{d} \Rightarrow d = \dfrac{8.85 \times 10^{-12}(4)(0.09\ \text{m}^2)}{2\ \mu\text{F}} = \mathbf{1.593\ \mu m}$

12. a. $C = 8.85 \times 10^{-12}(1)\dfrac{(0.08\ \text{m}^2)}{0.2\ \text{mm}} = \mathbf{3.54\ nF}$

b. $\mathscr{E} = \dfrac{V}{d} = \dfrac{200\ \text{V}}{0.2\ \text{mm}} = 10^6\ \text{V/m}$

c. $Q = CV = (3.54\ \text{nF})(200\ \text{V}) = \mathbf{0.708\ \mu C}$

14. #12: $0.2 \times 10^{-3}\ \cancel{\text{m}}\left[\dfrac{39.37\ \cancel{\text{in.}}}{1\ \cancel{\text{m}}}\right]\left[\dfrac{1\ \text{mil}}{10^{-3}\ \cancel{\text{in.}}}\right] = 7.874\ \text{mils}$

$\dfrac{75\ \text{V}}{\cancel{\text{mil}}}[7.874\ \cancel{\text{mils}}] = \mathbf{590.55\ V}$

#13: $\dfrac{400\ \text{V}}{\cancel{\text{mil}}}[7.874\ \cancel{\text{mils}}] = \mathbf{3{,}149.60\ V}$

16. mica: $\dfrac{1250\ \text{V}}{\dfrac{5000\ \text{V}}{\text{mil}}} = 1250\ \cancel{\text{V}}\left[\dfrac{\text{mil}}{5000\ \cancel{\text{V}}}\right] = \mathbf{0.25\ mils}$

18. a. $\tau = RC = (10^6\ \Omega)(5\ \mu\text{F}) = 5\ \text{s}$

b. $v_C = E(1 - e^{-t/\tau}) = \mathbf{20(1 - e^{-t/5})}$

c. $1\tau = \mathbf{12.64\ V}$, $3\tau = \mathbf{19\ V}$, $5\tau = \mathbf{19.87\ V}$

d. $i_C = \dfrac{20\ \text{V}}{1\ \text{M}\Omega}e^{-t/\tau} = \mathbf{20 \times 10^{-6}e^{-t/5}}$

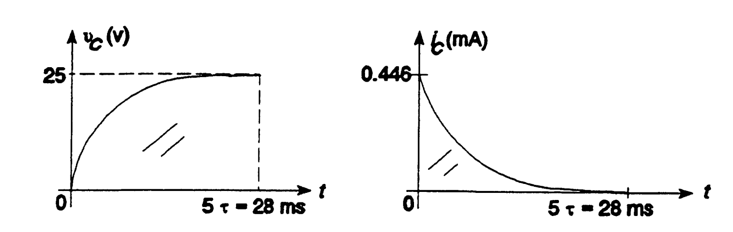
$v_R = Ee^{-t/\tau} = \mathbf{20e^{-t/5}}$

e. Same as 17 with $5\tau = 25$ s and $I_m = 20\ \mu$A

20. a. $\tau = RC = (56\text{ k}\Omega)(0.1\ \mu\text{F}) = \mathbf{5.6\ ms}$ b. $v_C = E(1 - e^{-t/\tau}) = 25(1 - e^{-t/5.6\text{ms}})$

c. $i_C = \frac{E}{R}e^{-t/\tau} = \frac{25\text{ V}}{56\text{ k}\Omega}e^{-t/\tau} = \mathbf{0.446 \times 10^{-3}e^{-t/5.6ms}}$

d. 



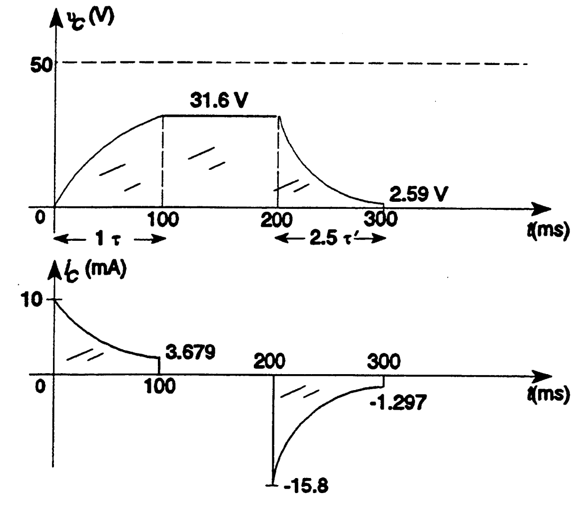
22. a. $\tau = RC = (5\text{ k}\Omega)(20\ \mu\text{F}) = \mathbf{100\ ms}$ b. $v_C = \mathbf{50(1 - e^{-t/100ms})}$

c. $i_C = \mathbf{10 \times 10^{-3}e^{-t/100ms}}$

d. $v_C = 50(1 - e^{-1}) = 50(1 - 0.3679) = 50(0.6321) = \mathbf{31.6\ V}$
$i_C = 10 \times 10^{-3}e^{-1} = 10 \times 10^{-3}(0.3679) = \mathbf{3.679\ mA}$

e. $\tau' = RC = (2\text{ k}\Omega)(20\ \mu\text{F}) = 40\text{ ms}$
$v_C = \mathbf{31.6e^{-t/40ms}}$
$i_C = \frac{31.6\text{ V}}{2\text{ k}\Omega}e^{-t/40\text{ms}} = \mathbf{15.8 \times 10^{-3}e^{-t/40ms}}$

f. At $t = 2.5\ \tau'$ (from 200 ms) → at 300 ms
$v_C = 31.6e^{-2.5} = 31.6(0.0821) = 2.59\text{ V}$
$i_C = 15.8 \times 10^{-3}e^{-2.5} = 1.297\text{ mA}$



24. $\tau = RC = (2.2\text{ k}\Omega)(2000\ \mu\text{F}) = 4.4\text{ s}$
$v_C = V_Ce^{-t/\tau} = \mathbf{40e^{-t/4.4}}$
$i_C = \frac{V_C}{R}e^{-t/\tau} = \frac{40\text{ V}}{2.2\text{ k}\Omega}e^{-t/4.4} = \mathbf{18.18 \times 10^{-3}e^{-t/4.4}}$
$v_R = v_C = \mathbf{40e^{-t/4.4}}$

26. a. $\tau = RC = (4.7\text{ k}\Omega)(10\ \mu\text{F}) = 47\text{ ms}$

$v_C = V_f + (V_i - V_f)e^{-t/\tau}$

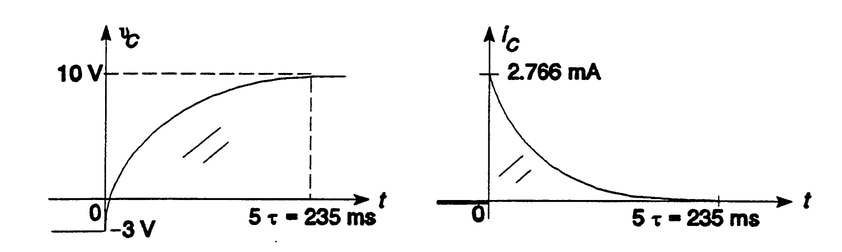
$= 10\text{ V} + (-3\text{ V} - 10\text{ V})e^{-t/47\text{ ms}}$

$v_C = \mathbf{10\ V - 13\ V}e^{\mathbf{-t/47\ ms}}$

$v_R(0+) = 10\text{ V} + 3\text{ V} = 13\text{ V}$

$i_C = \dfrac{13\text{ V}}{4.7\text{ k}\Omega}e^{-t/47\text{ ms}} = \mathbf{2.766\ mA}e^{\mathbf{-t/47\ ms}}$

b.



28. a. $V_C = 8(1 - e^{-5\tau/\tau}) = 8(1 - e^{-5}) = 8(1 - 0.00674) = \mathbf{7.946\ V}$

b. $V_C = 8(1 - e^{-10}) = 8(1 - 0.0000454) = \mathbf{7.996\ V}$

c. $V_C = 8(1 - e^{-5\times10^{-6}/20\times10^{-6}}) = 8(1 - e^{-0.25}) = 8(1 - 0.7788) = \mathbf{1.7696\ V}$

30. $\tau = RC = (33\text{ k}\Omega)(20\ \mu\text{F}) = 0.66\text{ s}$

$v_C = 12(1 - e^{-t/0.66})$

$8 = 12(1 - e^{-t/0.66})$

$8 = 12 - 12e^{-t/0.66}$

$-4 = -12e^{-t/0.66}$

$0.333 = e^{-t/0.66}$

$\log_e 0.333 = -t/0.66$

$-1.0996 = -t/0.66$

$t = 1.0996(0.66) = \mathbf{0.726\ s}$

32. a. $\tau = (R_1 + R_2)C = (20\text{ k}\Omega)(6\ \mu\text{F}) = 0.12\text{ s}$

$v_C = E(1 - e^{-t/\tau})$

$60\text{ V} = 80\text{ V}(1 - e^{-t/0.12\text{s}})$

$0.75 = 1 - e^{-t/0.12\text{s}}$

$0.25 = e^{-t/0.12\text{s}}$

$t = -(0.12\text{ s})(-1.386)$

$= \mathbf{0.166\ s}$

b. $i_C = \dfrac{E}{R}e^{-t/\tau}$

$i_C = \dfrac{80\text{ V}}{20\text{ k}\Omega}e^{-\frac{0.166\text{s}}{0.12\text{s}}} = 4\text{ mA}\ e^{-1.383}$

$= (4\text{ mA})(0.2508)$

$\cong \mathbf{1\ mA}$

c. $i_s = i_C = 4\text{ mA } e^{-t/\tau} = 4\text{ mA } e^{-2\tau/\tau} = 4\text{ mA } e^{-2}$
$= 4\text{ mA}(0.1353)$
$= 0.541\text{ mA}$
$P_s = EI_s = (80\text{ V})(0.541\text{ mA})$
$= \mathbf{43.28\text{ mW}}$

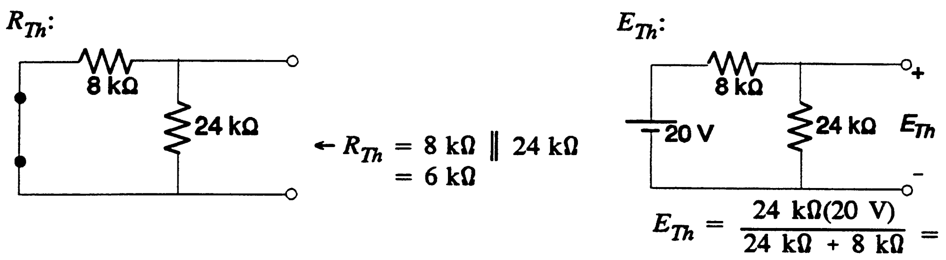
34. a. $v_m = v_R = Ee^{-t/\tau} = 60\text{ V } e^{-1\tau/\tau} = 60\text{ V } e^{-1}$
$= 60\text{ V}(0.3679)$
$= \mathbf{22.074\text{ V}}$

b. $i_C = \dfrac{E}{R}e^{-t/\tau} = \dfrac{60\text{ V}}{10\text{ M}\Omega}e^{-2\tau/\tau} = 6\ \mu\text{A } e^{-2}$
$= 6\ \mu\text{A}(0.1353)$
$= \mathbf{0.812\ \mu A}$

c. $v_C = E(1 - e^{-t/\tau})$ $\quad\tau = RC = (10\text{ M}\Omega)(0.2\ \mu\text{F}) = 2\text{ s}$
$50\text{ V} = 60\text{ V}(1 - e^{-t/2s})$
$0.8333 = 1 - e^{-t/2s}$
$\log_e 0.1667 = -t/2s$
$t = -(2s)(-1.792)$
$= \mathbf{3.584\text{ s}}$

36. a. Thevenin's theorem:

R_{Th}: E_{Th}:



$\leftarrow R_{Th} = 8\text{ k}\Omega \parallel 24\text{ k}\Omega = 6\text{ k}\Omega$

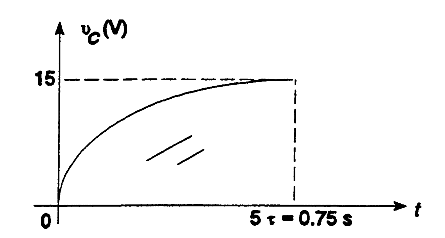
$E_{Th} = \dfrac{24\text{ k}\Omega(20\text{ V})}{24\text{ k}\Omega + 8\text{ k}\Omega} = 15\text{ V}$

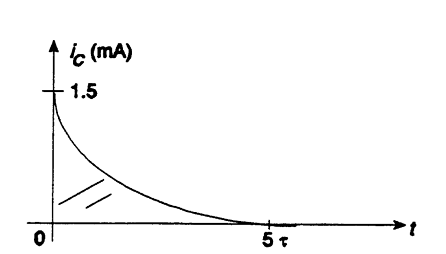
$\tau = RC = (10\text{ k}\Omega)(15\ \mu\text{F}) = 0.15\text{ s}$
$v_C = E(1 - e^{-t/\tau})$
$= \mathbf{15(1 - e^{-t/0.15})}$

$i_C = \dfrac{E}{R}e^{-t/\tau} = \dfrac{15\text{ V}}{10\text{ k}\Omega}e^{-t/0.15} = \mathbf{1.5 \times 10^{-3}e^{-t/0.15}}$

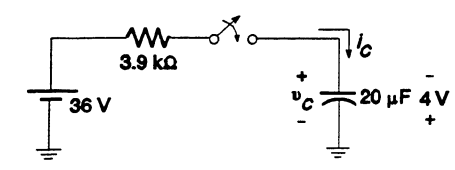
b.





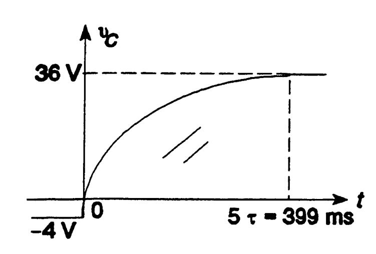


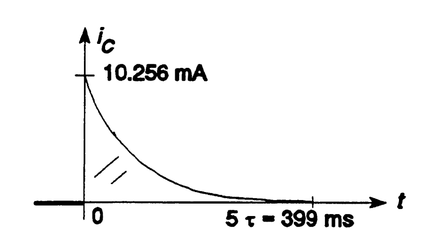
38. a. $R_{Th} = 3.9\text{ k}\Omega + 0\ \Omega \parallel 1.8\text{ k}\Omega = 3.9\text{ k}\Omega$
$E_{Th} = 36\text{ V}$



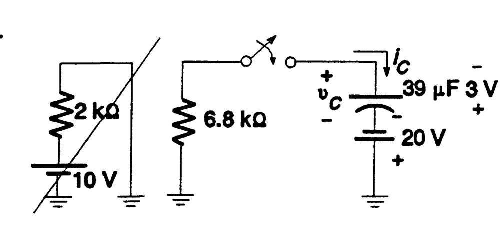
$\tau = RC = (3.9\text{ k}\Omega)(20\ \mu\text{F}) = 78\text{ ms}$
$v_C = V_f + (V_i - V_f)e^{-t/\tau}$
$= 36\text{ V} + (-4\text{ V} - 36\text{ V})e^{-t/78\text{ ms}}$
$\mathbf{v_C = 36\text{ V} - 40\text{ V}e^{-t/78\text{ ms}}}$
$v_R(0+) = 36\text{ V} + 4\text{ V} = 40\text{ V}$
$i_C = \dfrac{40\text{ V}}{3.9\text{ k}\Omega}e^{-t/78\text{ ms}}$
$\mathbf{i_C = 10.256\text{ mA}e^{-t/78\text{ ms}}}$

b.



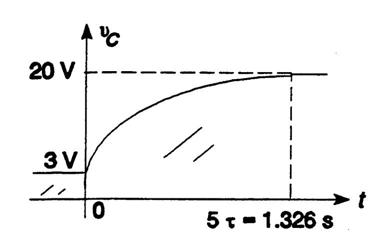


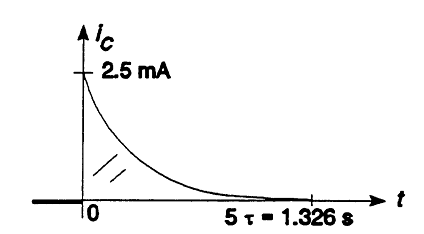
40. a.



$\tau = RC = (6.8\text{ k}\Omega)(39\ \mu\text{F}) = 265.2\text{ ms}$
$v_C = V_f + (V_i - V_f)e^{-t/\tau}$
$= 20\text{ V} + (3\text{ V} - 20\text{ V})e^{-t/265.2\text{ ms}}$
$\mathbf{v_C = 20\text{ V} - 17\text{ V}e^{-t/265.2\text{ ms}}}$
$v_R(0+) = 20\text{ V} - 3\text{ V} = 17\text{ V}$
$i_C = \dfrac{17\text{ V}}{6.8\text{ k}\Omega}e^{-t/265.2\text{ ms}}$
$\mathbf{i_C = 2.5\text{ mA}e^{-t/265.2\text{ ms}}}$

b.





42. $i_C = C\dfrac{\Delta V}{\Delta t} = 0.06 \times 10^{-6}\ \dfrac{\Delta V}{\Delta t}$

$0 \rightarrow 2\ \mu\text{s}$: $i_C = 0.06 \times 10^{-6}\left[\dfrac{3\text{ V}}{2\ \mu\text{s}}\right] = 90\text{ mA}$

$2 \rightarrow 4\ \mu\text{s}$: $i_C = -0.06 \times 10^{-6}\left[\dfrac{6\text{ V}}{2\ \mu\text{s}}\right] = -180\text{ mA}$

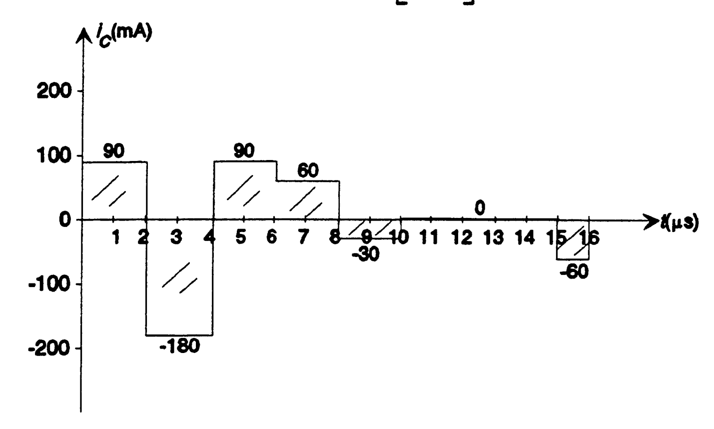
$4 \rightarrow 6\ \mu\text{s}$: $i_C = 0.06 \times 10^{-6}\left[\dfrac{3\text{ V}}{2\ \mu\text{s}}\right] = 90\text{ mA}$

$6 \rightarrow 8\ \mu\text{s}$: $i_C = 0.06 \times 10^{-6}\left[\dfrac{2\text{ V}}{2\ \mu\text{s}}\right] = 60\text{ mA}$

$8 \rightarrow 10\ \mu s$: $i_C = -0.06 \times 10^{-6}\left[\frac{1\text{ V}}{2\ \mu\text{s}}\right] = -30\text{ mA}$

$10 \rightarrow 15\ \mu s$: $i_C = 0\text{ mA}$

$15 \rightarrow 16\ \mu s$: $i_C = -0.06 \times 10^{-6}\left[\frac{1\text{ V}}{1\ \mu\text{s}}\right] = -60\text{ mA}$



44. a. $C_T = 0.2\ \mu F \parallel (2\ \mu F + 7\ \mu F) = \mathbf{0.1957\ \mu F}$

b. $C_T = 20\text{ pF} + 60\text{ pF} \parallel (10\text{ pF} + 30\text{ pF}) = \mathbf{44\text{ pF}}$

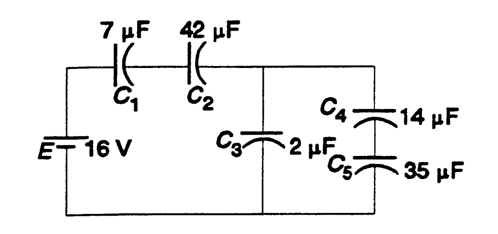
46. a.

C_1 9 μF, E 24 V, C_2 10 μF, C_3 9 μF, C_4 72 μF

$$\frac{(9\ \mu F)(72\ \mu F)}{9\ \mu F + 72\ \mu F} = 8\ \mu F$$
$$8\ \mu F + 10\ \mu F = 18\ \mu F$$
$$\frac{(9\ \mu F)(18\ \mu F)}{9\ \mu F + 18\ \mu F} = 6\ \mu F$$

$$C_T = \frac{Q}{V} = \frac{Q}{E} \Rightarrow Q = C_T E = (6\ \mu F)(24\text{ V}) = 144\ \mu C$$
$$Q_1 = \mathbf{144\ \mu C}$$
$$V_1 = \frac{Q_1}{C_1} = \frac{144\ \mu C}{9\ \mu F} = \mathbf{16\text{ V}}$$
$$V_2 = E - V_1 = 24\text{ V} - 16\text{ V} = \mathbf{8\text{ V}}$$
$$Q_2 = C_2 V_2 = 10\ \mu F(8\text{ V}) = \mathbf{80\ \mu C}$$
$$Q_{3-4} = C'V = (8\ \mu F)(8\text{ V}) = 64\ \mu C$$
$$Q_3 = Q_4 = \mathbf{64\ \mu C}$$
$$V_3 = \frac{Q_3}{V_3} = \frac{64\ \mu C}{9\ \mu F} = \mathbf{7.111\text{ V}}$$
$$V_4 = \frac{Q_4}{V_4} = \frac{64\ \mu C}{72\ \mu F} = \mathbf{0.889\text{ V}}$$

b.



$$\frac{(14\ \mu F)(35\ \mu F)}{14\ \mu F + 35\ \mu F} = 10\ \mu F$$
$$2\ \mu F + 10\ \mu F = 12\ \mu F$$
$$\frac{(7\ \mu F)(42\ \mu F)}{7\ \mu F + 42\ \mu F} = 6\ \mu F$$
$$C_T = \frac{(6\ \mu F)(12\ \mu F)}{6\ \mu F + 12\ \mu F} = 4\ \mu F$$

$$Q = CV = (4\ \mu F)(16\ V) = 64\ \mu C$$
$$Q_1 = Q_2 = \mathbf{64\ \mu C}$$
$$V_1 = \frac{Q_1}{C_1} = \frac{64\ \mu C}{7\ \mu F} = \mathbf{9.143\ V}$$
$$V_2 = \frac{Q_2}{C_2} = \frac{64\ \mu C}{42\ \mu F} = \mathbf{1.524\ V}$$
$$V_3 = E - V_1 - V_2 = 16\ V - 9.143\ V - 1.524\ V = \mathbf{5.333\ V}$$
$$Q_3 = C_3V_3 = (2\ \mu F)(5.333\ V) = 10.667\ \mu C$$
$$Q' = CV = (10\ \mu F)(5.333\ V) = 53.33\ \mu C$$
$$Q_4 = Q_5 = \mathbf{53.33\ \mu C}$$
$$V_4 = \frac{Q_4}{C_4} = \frac{53.33\ \mu C}{14\ \mu F} = \mathbf{3.809\ V}$$
$$V_5 = \frac{Q_5}{C_5} = \frac{53.33\ \mu C}{35\ \mu F} = \mathbf{1.524\ V}$$

48. a. $V_{4k\Omega} = \dfrac{4\ k\Omega(48\ V)}{4\ k\Omega + 2\ k\Omega} = \mathbf{32\ V} = V_{0.08\mu F}$

$Q_{0.08\mu F} = (0.08\ \mu F)(32\ V) = \mathbf{2.56\ \mu C}$

$V_{0.04\mu F} = \mathbf{48\ V}$

$Q_{0.04\mu F} = (0.04\ \mu F)(48\ V) = \mathbf{1.92\ \mu C}$

b. $V_{6k\Omega} = \dfrac{6\ k\Omega(80\ V)}{6\ k\Omega + 4\ k\Omega} = \mathbf{48\ V} = V_{60\mu F}$

$Q_{60\mu F} = (60\ \mu F)(48\ V) = \mathbf{2880\ \mu C}$

$V_{40\mu F} = \mathbf{80\ V}$

$Q_{40\mu F} = (40\ \mu F)(80\ V) = \mathbf{3200\ \mu C}$

50. $W = \dfrac{Q^2}{2C} \Rightarrow Q = \sqrt{2CW} = \sqrt{2(6\ \mu F)(1200\ J)} = \mathbf{0.12\ C}$

52. a. $V_{6\mu F} = V_{12\mu F} = \dfrac{3\ k\Omega(24\ V)}{3\ k\Omega + 6\ k\Omega} = 8\ V$

$W_{6\mu F} = \dfrac{1}{2}CV^2 = \dfrac{1}{2}(6\ \mu F)(8\ V)^2 = \mathbf{0.192\ mJ}$

$W_{12\mu F} = \dfrac{1}{2}CV^2 = \dfrac{1}{2}(12\ \mu F)(8\ V)^2 = \mathbf{0.384\ mJ}$

b. $C_T = \dfrac{(6\ \mu\text{F})(12\ \mu\text{F})}{6\ \mu\text{F} + 12\ \mu\text{F}} = 4\ \mu\text{F}$

$Q_T = C_T V = (4\ \mu\text{F})(8\ \text{V}) = 32\ \mu\text{C}$

$Q_{6\mu\text{F}} = Q_{12\mu\text{F}} = 32\ \mu\text{C}$

$V_{6\mu\text{F}} = \dfrac{Q}{C} = \dfrac{32\ \mu\text{C}}{6\ \mu\text{F}} = 5.333\ \text{V}$

$V_{12\mu\text{F}} = \dfrac{Q}{C} = \dfrac{32\ \mu\text{C}}{12\ \mu\text{F}} = 2.667\ \text{V}$

$W_{6\mu\text{F}} = \dfrac{1}{2}CV^2 = \dfrac{1}{2}(6\ \mu\text{F})(5.333\ \text{V})^2 = \mathbf{85.32\ \mu J}$

$W_{12\mu\text{F}} = \dfrac{1}{2}CV^2 = \dfrac{1}{2}(12\ \mu\text{F})(2.667\ \text{V})^2 = \mathbf{42.68\ \mu J}$